Overview on Fire Detection in Japan

AKIO WATANABE and HIROAKI SASAKI
Fire Research Institute, Fire Defence Agency
3-14-1, Nakahara, Mitaka, Tokyo 181, Japan

JUZO UNOKI
Nohmi Bosai Kogyo Co., Ltd.
4-7-3, Kudan-Minami, Chiyoda-ku, Tokyo 102, Japan

ABSTRACT

Some of unexpected fires may self-extinguish due to insufficient heat re-
lease or air supply and some may be discovered and controlled by occupants.
Accordingly an automatic fire detection system plays an important role in cases
where effective human detection measures couldn't be expected. In Japan, auto-
matic fire detection systems have been obligatorily installed in buildings for
specific uses having a floor space above a certain value as prescribed by the
Fire Service Law. Automatic fire detection systems seem to be considerably
effective but there are many cases where the bell of the control unit does not
operate because the custodians of the buildings keep the bell switched off in
order to avoid false alarms. The probabilities of giving false alarm per year
per detector are 6.5% in smoke detectors and 0.8% in heat detectors. There
seem to be two current trends in the solution of false alarm problems. One is
"right detector in the right place" and the other is to increase the informa-
tion content on which discrimination between genuine fires and fire simulating
phenomena can be made. Several methods have already been put into practice to
greatly reduce the probability of false alarm occurrence to 1%/year·detector,
and much more sophisticated fire detection systems will be adopted in near
future.

INTRODUCTION

Fire detection technique has made great progress for the past 25 years,
and the use of automatic fire detection systems is felt to be closer to accept-
ance by the general public. In Japan, the annual output of fire detectors has
increased from 80,000 in 1954 to 5 million in 1984, and they have been obliga-
torily installed in buildings for specific uses having a floor space above a
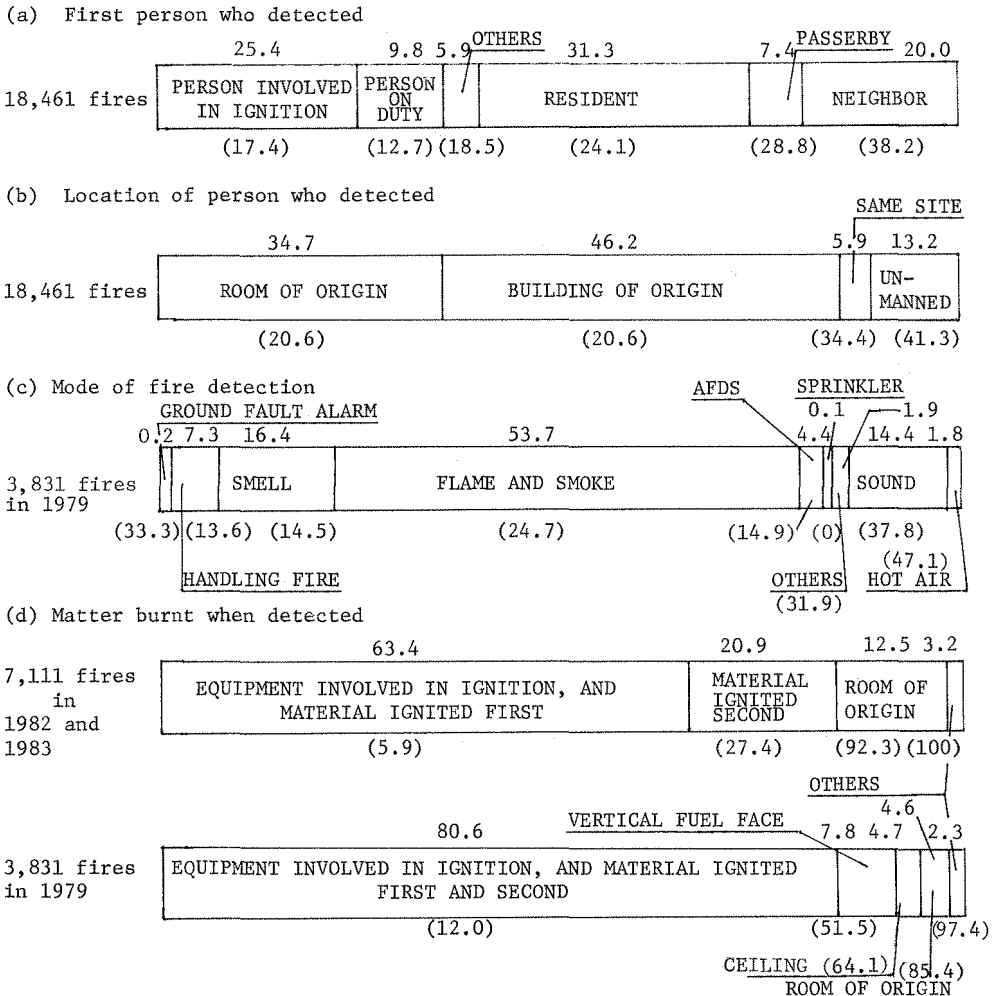certain value as prescribed by the Fire Service Law.

At present, the reliability of detectors can be easily confirmed by vari-
ous testing methods and life prediction methods. However, to pursue more ef-
fective fire detection methods, the following should be considered;

a) from ignition to extinction, there are many fire-developing stages and
    corresponding systems, each of which consists of many sub-systems and
    components and achieves the mission under different conditions, and,

b) even if the reliability of a hardware system is high, the system ef-
    fectiveness will be considerably affected by the human attitude to-
    wards the system and fire.

The present paper describes the role of human and hardware systems in fire detection and touches on the improvement of the system effectiveness.

ROLE OF HUMAN AND HARDWARE SYSTEMS IN FIRE DETECTION

Most of the unexpected fires are caused by human activities at their living place. So, there may be frequently somebody near the fire origin. If he is the person involved directly in the ignition, it's natural that he may well discover the fire first. FIGURE 1 (a) illustrates the first persons who detected the fires inside building between 1979 and 1983 in Tokyo. The figure also gives a transition probability of fire spread from "small fire" to

(a) First person who detected

	25.4	9.8	5.9	OTHERS	31.3		7.4	PASSERBY	20.0
18,461 fires	PERSON INVOLVED IN IGNITION	PERSON ON DUTY		/	RESIDENT			/	NEIGHBOR
	(17.4)	(12.7)	(18.5)		(24.1)		(28.8)		(38.2)

(b) Location of person who detected

SAME SITE

	34.7	46.2	5.9	13.2
18,461 fires	ROOM OF ORIGIN	BUILDING OF ORIGIN		UN-MANNED
	(20.6)	(20.6)	(34.4)	(41.3)

(c) Mode of fire detection   AFDS   SPRINKLER

GROUND FAULT ALARM

	0.2	7.3	16.4	53.7		4.4	0.1	14.4	1.9	1.8
3,831 fires in 1979			SMELL	FLAME AND SMOKE				SOUND		
	(33.3)	(13.6)	(14.5)	(24.7)		(14.9)	(0)	(37.8)		

HANDLING FIRE   OTHERS   HOT AIR
                                                        (31.9)
                                                                    (47.1)

(d) Matter burnt when detected

	63.4	20.9	12.5	3.2
7,111 fires in 1982 and 1983	EQUIPMENT INVOLVED IN IGNITION, AND MATERIAL IGNITED FIRST	MATERIAL IGNITED SECOND	ROOM OF ORIGIN	
	(5.9)	(27.4)	(92.3)	(100)

OTHERS
                                                                 4.6
                              VERTICAL FUEL FACE   7.8 4.7   2.3

	80.6	
3,831 fires in 1979	EQUIPMENT INVOLVED IN IGNITION, AND MATERIAL IGNITED FIRST AND SECOND	
	(12.0)	(51.5) (97.4)

CEILING (64.1) (85.4)
ROOM OF ORIGIN

Note : Values above colume ; %
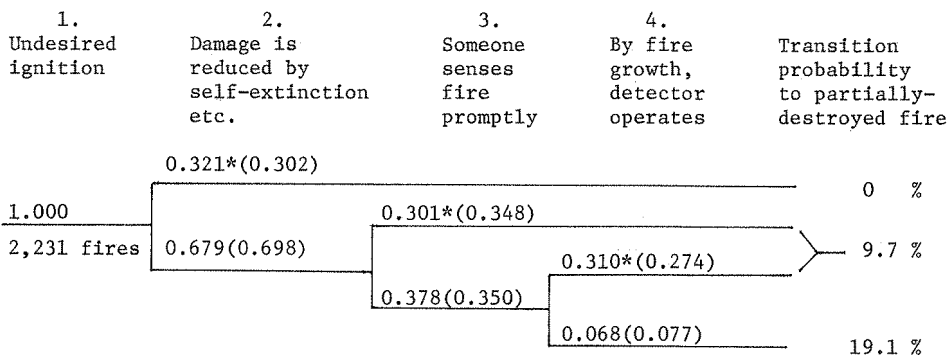   Those below colume (in parentheses); fire spread probability (%)
FIGURE 1. Human detectors

680

"partially-destroyed fire" as one of the indexes showing the effect of detection methods. In this paper, "small fire" means that the burnt floor space is below 3.3 sq. m and the ratio of fire loss to the assessed value of the building is below 10%, while "partially-destroyed fire" means that the loss is over that of small fire.

Other questions would be where, how and when the person discovers the fire. The answers are shown in FIGURE 1 (b) - (d). From these figures, it may be concluded;

a) both fires during people's absence and the fires discovered by a guard are increased by the recent reduction of the persons on night duty in Japan,

b) lesser loss does not always link with earlier detection, and seems to depend on locating the fire spot and human activities after detection, and,

c) the largest fire spread probability is associated with detection by sound and hot air, and a relatively smaller one can be expected with automatic detection; it may be noted that detection by smell leads to slight damage.

After unexpected ignition, some of fires may self-extinguish due to insufficient heat release or air supply, and some may be discovered by the occupant and extinguished with his hands and feet before an automatic fire detection system operates. Statistical analysis has been done for the fires in buildings in which an automatic detection system should be installed by the law, as shown in FIGURE 2. Since fires are often controlled by occupants before the detection system operates as in FIGURE 2, the system plays an important role in cases where effective human detection measures couldn't be expected.

1. Undesired ignition	2. Damage is reduced by self-extinction etc.	3. Someone senses fire promptly	4. By fire growth, detector operates	Transition probability to partially- destroyed fire

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                    0.321*(0.302)
                                                                      0   %
1.000         ┌──────────────────
              │             0.301*(0.348)
2,231 fires   │ 0.679(0.698) ┌──────────────
              │              │          0.310*(0.274)    ├── 9.7 %
              │              └ 0.378(0.350) ┌────────────
                                            │ 0.068(0.077)
                                                                     19.1 %
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Note : * ; probability of success
       Number in parentheses ; obtained by the last investigation

FIGURE 2.   Probabilities of fire detection

EFFECTIVENESS OF AUTOMATIC FIRE DETECTION SYSTEM

FIGURE 3 shows the result of the above-mentioned statistical analysis. It is seen from this figure that the fire spread probability is a little over 7% for the buildings fully protected by the automatic fire detection system and 24% for the buildings not yet equipped, that is, when the system is installed, the fire spread probability would be reduced by a factor of 3.4 as against that of non-protected buildings.

The Tokyo Fire Department have surveyed 2006 fires which occurred during 6 years from 1976 to 1981 in buildings where automatic fire detection systems are installed. According to this report, 726 fires of the surveyed fires were detected first by the automatic fire detection systems and 797 fires were alarmed by these systems although they were detected first by human. Therefore, 1523 fires, that is, 76% of total fires were successfully detected by automatic fire detection systems. In the remainder, 309 fires, 15.4% of total fires occurred where no fire detector was installed, and 174 fires, 8.7% of total fires could not be detected by the automatic fire detection systems. 76% of these 174 unsuccessful cases happened because the bell of the control unit did not operate due to fault of management (56% were caused by stopping the bell and 20% by cutting off the power supply). This fact indicates that false alarms were caused so frequently that the custodian of the building kept the bell switched off in order to avoid false alarms.

As to reliability of equipments, Japan Fire Equipment Inspection Institute made investigation on the degree of changes in function of 670 thermal and smoke detectors in operation under severe environmental condition for more than five years. According to this result a large number of detectors were found to show considerable changes in their function particularly among those installed in spa if classified by districts of their installation, and those in hotels and factories if classified by occupancies of buildings.

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                                                                P (%)
ALREADY      PROTECTED AREA (2,231)                              7.2
INSTALLED   ┌──────────────────────────────────────────────┐         ┐
            │                    AREA WHICH NEED NOT INSTALL (87)  9.2 │ 7.5
(2,348)     │ UNPROTECTED AREA  ├──────────────────────────┤     ├13.7┘
            └                    PARTIALLY-UNPROTEC. AREA (30)   26.7 ┘

NOT YET INSTALLED (133 BETWEEN 1979 - 1981)                     24.2
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Note : Number in parentheses ; the number of fires

FIGURE 3. Transition probability to partially-destroyed fire; P, in buildings where automatic fire detection system should be installed

ACTUAL CIRCUMSTANCES OF FALSE ALARM

At the second half of 1960's, the ratios of false alarms to genuine fire alarms were 3.9 : 1 in Japan and 11.1 : 1 in England. The ratio in England was 23.8 : 1 in 1971 according to the British Fire Protection Systems Association. The reasons for world-wide increasing tendency of the ratio may be frequent use of smoke detectors for fire-safety, and the adoption of powerful air conditioning units and airtight building structures.

In grasping the causes of false alarm, we meet with the following difficulties.

a) it's difficult to decide on the detector giving false alarm, as plural detectors with different principles are connected in one circuit,

b) it's very rare to give false alarm at a specified place, and false alarm is frequently caused by a very quick phenomenon, and,

c) the users are apt to complain of the operation by heat or smoke produced by everyday life, as false alarm, especially in case of the obligatory installation.

The recent statistical analysis on false alarm were reported (a) on 2,787 false alarms of smoke detectors by the Association of Fire Alarm of Japan and the Tokyo Fire Alarm Maintenance Corporative Association in 1977, (b) on 553 false alarms by the Fire Equipment Safety Center of Japan, and on 7,469 false alarms in 1,500 buildings by the Tokyo Fire Department in 1982. Although some of the results were already presented in the English language, the main findings are summarized as follows;

a) the number of false alarms, classified by month, shows the highest value between July and September.

b) the number, classified by hour, shows the highest value at 7 to 9 o'clock in the morning, and then human activities seem to affect the false alarm.

c) though half to 1/3 of false alarms could't be traced to the causes, the causes mentioned were strong wind, maintenance, high humidity, artificial smoke etc. in a report, while they were cooking, smoking, exhause gases etc. in a recent report, putting the causes in order of the frequency.

d) the probabilities of giving false alarm per year per detector are summarized in TABLE 1.

The above findings suggest that,

a) most of false alarms from smoke detectors are caused by normal combustion and heating in daily life such as smoking and cooking. False alarm of fixed temperature type detectors can be explained as they are installed under severe conditions,

b) the probabilities in the place of living and kitchen were maximum 5.6%/year·detector and 41.6%/year·detector, respectively,

c) the delay type smoke detectors could be expected to give less false alarms.

TABLE 1. Probability (%), of giving alarm per year·detector

Alarm given by	Probability of giving alarm per year detector (%)				
	Smoke		Heat		
	Ioni-zation	Photo-electric	Fixed temp.	Rate-of-rise	
				Spot	Line
Genuine fire	0.08 (0)	0.12 (0)	0	0.06	0
Combustion or heating in daily life	4.36 (0.47)	0.87 (0)	2.46	0.03	0
Environmental factors having no connection with comb. or heating	0.63 (0.23)	0.56 (0.27)	0	0.06	0
Device/system defect or bad maintenance	0.04 (0.12)	0.19 (0)	0.30	0.06	0
Unknown cause	3.11 (0.70)	1.68 (0)	1.49	0.67	0
TOTAL EXCEPT THOSE BY GENUINE FIRE	8.14 (1.52)	3.30 (0.27)	4.25	0.82	0

No. of detectors; 12,980 (Smoke ones 65.4%)

No. of false alarms; 553 (during a year)

TOKYO FIRE DEPT's FALSE ALARM DATA	6.5	0.8

No. of detectors; 262,152 (smoke ones 37.5%)

No. of false alarms; 7.469 (during a year)

684

MUCH BETTER SYSTEM

As mentioned above, there are a wide range of possible causes of false alarm. Therefore, the problem of the false alarm may be difficult to solve by a single method. There seem to be two current trends in its solutions.

One is "right detector in the right place" by using interchangeable mounting-base. This is quite a realistic solution. The other is to increase the information content as to complicated fire situations and occupants' activities. Most of the present detectors are of one-parameter and one-threshold value. They give alarm when a fire characteristics parameter exceeds the predetermined threshold value. Indeed, the fire is accompanied with heat, smoke, radiation, gas etc., but fire is not a unique source for the sensor output. Several misleading phenomena could be the source giving alarm, too. In this way it is possible for detector to give false alarm, and it is necessary to increase the information content on which discrimination between genuine fires and fire simulating phenomena is made.

Up to now, from the viewpoint of the maintenance of detectors and the signal processing, there have been proposed several methods as follows.

Adoption of multiple confirmation or integral circuit

This system checks whether the output of sensor is temporary or continuous. If the former is the case, the alarm is not given. For example, it is generally said that the use of time delay type detector is expected to decrease the false alarms by 45%.

Detector with individual address

To identify the detector giving alarm, the addition of individual detector address has been proposed in recent years. The outputs of devices with ability of transmitting such an address in 1984 were about 2,000 detectors and 17,000 relaying devices having encoder. The most sophisticated system is able to remotely check the detector sensitivity; replacing the defective detectors resulted in probability of the false alarm occurrence of 0.15%/year.detector.

Sensitivity-floating detection systems

The sensitivity level is automatically set corresponding to ambient conditions such as the start of strong heating and air conditioning system.

Line type or areal type detection systems

This example is the smoke detection method measuring light-extinction over long paths. Its independence of localized heat or smoke would decrease the false alarm.

Multi-stage detector

This can give several stages of alarms corresponding to the progress of fire.

Combined or compensation type detector

This detector is exemplified by the composite of 2 kinds of sensors so that the threshold level of smoke detector become more sensitive with temperature rise.

Application of pattern recognition method

The processes of this method are as follows.

1. Storage of data on fire characteristic values in fires and normal conditions.
2. Extraction of fire features, i.e. grasp of time variation and/or spatial distribution of fire characteristics as patterns.
3. Comparison between patterns of fire characteristic values and of measured quantity.
4. Discrimination between genuine fires and deceptive phenomena.

Thus, the system can avoid giving the false alarm. But the fire pattern is dynamic in actual fires, and so real time recognition is desirable. In this point this method is different from the ordinary pattern recognition, which is static. Citing the present examples, the pattern recognition type fire detection systems have been developed by the Japan National Railway since the most of train fires occur in specific places such as overheat of the devices under the floor in Japan. The other relates to the visual organ of intelligent fire fighting robots.

CONCLUSION

Some of above-mentioned methods have already been put into practice to greatly reduce the probability of false alarm occurrence to 1%/year.detector. Even if the probability of individual detector is low, when more than one thousand detectors are installed in one building, the owner may suffer from false alarm. Also, if all automatic fire detection systems in a municipality are directly connected to a fire department, the department is driven by necessity for the solution of false alarm. In these two cases, the accumulated number of false alarms in the system cannot be generously tolerable despite of the low probability.

In these years we are experiencing drastic reduction in cost of semiconductor components as well as great progress of information analysis technology, which will make it possible to adopt much more sophisticated fire detection systems as solution for the false alarm problem (cf. REFERENCE 11 $\sim$ 17).

Both pertinent human actions after detection of fire and the maintenance of the system are indispensable to effective application of the system. Therefore, the important future problem is how the system assists human beings. In other words, the goal of the system must be foolproof or fail-safe. Remembering the fire detection system is of us, by us and for us; we must get along with this honest device for our safety life.

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